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OPERATIONAL TESTS OF TWO VISCOUS DAP FIRE RETARDANTS

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ABSTRACT: Operational tests conducted from air tanker bases in California in 1962 confirmed earlier laboratory and field studies and showed that viscous solutions of diammonium phosphate (DAP) are more effective than any other presently known fire retardant. These tests also indicated that corrosion is not a serious problem if inhibitors are used and equipment is properly maintained. Some storage problems still remain.

Laboratory tests at Missoula, Montana (Hardy et al. 1962) and field tests at Plum Creek, California (Davis et al. 1962) indicated that, under the specific conditions of the tests, viscous solutions of diammonium phosphate (DAP) were superior to other retardants. However, we still needed to know how viscous DAP would mix, handle, and store under actual airbase conditions and how well it would perform on wildfires burning under a wide variety of weather, topography, and fuel conditions. To get at this information, we tested two retardants from two air tanker bases on 34 wildfires in California during the 1962 season.

Most varieties of viscous DAP are available commercially in a dry, bagged form which includes corrosion inhibitors, dyes, and preservatives. The materials mix easily with water in batch-type mixers, and can be kept in storage tanks for several months without serious loss in viscosity except possibly in some cases during the hot summer months. Drop patterns and vegetation coverage are excellent, and the residue that enters the soil may stimulate plant growth (Johansen 1962). Viscous DAP is, however, moderately expensive, costing something less than twenty cents per gallon, depending on the formulation and excluding transportation charges.

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RETARDANTS TESTED

Sodium carboxymethylcellulose-diammonium phosphate (CMC-DAP) and ammonium pectate-diammonium phosphate (pectin-DAP) were selected for operational testing because of their relative economy, their superior mixing and handling characteristics, and because they could be preblended and bagged. The CMC-DAP(using Hercules Powder Company CMC, Grade 7HSP) was mixed with water at slightly more than one pound per gallon of water; the pectin-DAP(using pectin from Ventura Coastal Lemon Company)was mixed at the rate of $1\frac{1}{2}$ pounds per gallon (table 1).

Table 1.--Characteristics of two viscous DAP fire retardants

Item	Pectin-DAP[1/]	CMC-DAP[2/]
Density		
In bulk	57 lbs./cu. ft.	59 lbs./cu. ft.
In solution	9.1 lbs./gal.	9.0 lbs./gal.
Viscosity (normal temp. range)	800-2,100 centipoise	1,000-1,500 centipoise
Color of solution	Rust	Bright red
Cost, bagged, F.O.B. plant		
Per pound	$0.110	$0.145
Per gallon of solution	.167	.159

1/ Free-flowing powder. Formulation (for 600 gals. of water): diammonium phosphate, 645 lbs.; ammonium pectate, 270 lbs.; "Versene," 30 lbs.; sodium silicofluoride, 9 lbs.; ferric oxide, 10 lbs. (sold in approximately this formulation as "PHOS-CHEK 100").

2/ Free-flowing powder. Formulation (for 600 gals. of water): diammonium phosphate, 600 lbs.; "CMC-7HSP," 60 lbs.; sodium silicofluoride, 9 lbs.; ferric oxide, 1 lb.; Rhodamine B dye, $\frac{1}{2}$ lb. (sold in approximately this formulation as "PHOS-CHEK 201").

TEST AREAS

Two air tanker initial-attack bases, one in northern, the other in southern California, were selected to test both CMC-DAP and pectin-DAP. The first location was the California Division of Forestry air tanker facility at Ukiah. From this base during the operational period of August 1 to October 15, three N3N air tankers used the materials on 30 wildfires. The Ukiah area provided an opportunity to evaluate the fire control effectiveness of viscous DAP on a large variety of vegetation types. Use on hardwood and redwood timber gave an excellent test of the material's ability to penetrate vegetation canopies (fig. 1).

Figure 1.--Viscous DAP controlled ground fire which approached from right under oak canopy.

Figure 2.--Edge of an island of unburned brush. Fire intensity is indicated by the clean burn on the unprotected area.

When the Ukiah airbase closed at the end of the fire season in northern California, the tests were moved to the joint U.S. Forest Service-California Division of Forestry airbase at Hemet in Riverside County. Here the material was used in TBM air tankers. During the 11 weeks that viscous DAP was tested, 4 TBM's made 17 drops on 4 fires in chaparral fuels typical of the area.

TEST PROCEDURES

Two methods of evaluating retardant effectiveness were used at each of the bases:

1. Pilots, drop coordinators, and ground fire control personnel who had been in a position to observe the drops were interviewed. Their comments were tape recorded when possible. Otherwise, they submitted a written report. Since we were usually able to talk to several people on each fire, we were able to verify most statements.

2. Research personnel assigned to the project attended most of the fires and observed and photographed retardant effectiveness during or shortly after the fire.

Where bentonite or borate was used on the same fire as viscous DAP, it was often possible to make a direct comparison.

PERFORMANCE

During the 5 months of operational testing:

1. There was no known case where fire burned through a viscous DAP line, although it did burn through adjacent drops of bentonite. A viscous DAP drop was occasionally outflanked, but the protected area remained as an island in the burn (fig. 2).

2. Viscous DAP retained its retardant effectiveness for long periods of time. Firefighters stated repeatedly that adjacent drops of bentonite and viscous DAP would each "knock the fire down." But if the fire continued to smolder, the bentonite would soon dry out and the fire would again start to spread. On the other hand, viscous DAP, because of its chemical properties, successfully held fires even though crews were delayed as long as two hours in reaching the area. There were numerous cases where spot fires were controlled in dense brush and no suppression action was taken in addition to the drop.

3. Good penetration characteristics made it possible for the pilots to do an effective job in spite of heavy crown covers of hardwood and conifers. This permitted air tankers to be used in areas previously thought unsuitable for air operations.

4. The retardants proved effective even though old-growth snags occasionally made it necessary to fly at more than 300 feet above the ground.

CHARACTERISTICS OF USE

COLORING

Poor drop visibility proved to be a problem with viscous DAP as it had with bentonite (Phillips and Miller 1959) and DAP water solutions (Johansen 1960)--after the first or second drop of the naturally greenish pectin-DAP, one of the pilots asked us if we were trying to camouflage the retardant.

Good visibility was achieved with 10 pounds of paint grade ferric oxide per 600 gallons of pectin-DAP solution. The pigment gave a rust color that was readily visible from the air. The cost was approximately 1/6 cent per gallon of retardant solution.

The clear CMC-DAP presented a different problem. We found we could get good visibility only after adding two materials: a ferric oxide for opaqueness and a dye for brillance. We added one pound of paint-pigment grade ferric oxide plus 1/2 pound of Rhodamine B 500-percent-concentration pink aniline dye to 600 gallons of the retardant solution. The result was a blood-red color that was visible under dense oak cover. The cost of the coloring was about 1/3 cent per gallon.

The ferric oxide was readily washed off equipment and out of clothing and has presented no problem. The Rhodamine B dye, which is also used in bentonite, is heat setting and should be washed off as soon as possible with cold water if staining is to be prevented. In general, pilots and airport crews have found that it is easier to clean viscous DAP from their equipment than either bentonite or borate, provided the job is done promptly.

MIXING AND HANDLING

Both of the viscous DAP retardants were easily mixed in a side-entry batch mixer of the type developed by the California Division of Forestry. The materials are, however, somewhat different in their mixing characteristics. Pectin-DAP reaches its highest viscosity after 2 or 3 minutes of mixing, and overmixing reduces viscosity (fig. 3). CMC-DAP, on the other hand, shows an increase in viscosity with time up to as much as 10 minutes of mixing although satisfactory results have been obtained with only 3 to 5 minutes of mixing.

Water temperature is also an important factor in the viscosity of the solution. CMC-DAP increases in viscosity as water temperature decreases (fig. 4). Ground crews at Hemet found a great increase in pump transfer time as the cooler winter months approached. Pectin-DAP increases in viscosity as water temperature increases up to 85°F. Above 85°, however, there is a drastic loss. Mixing pectin-DAP at temperatures below 40°F. is also difficult.

Laboratory studies have shown that viscosity of both materials is not seriously affected by the normal range in water hardness, but good

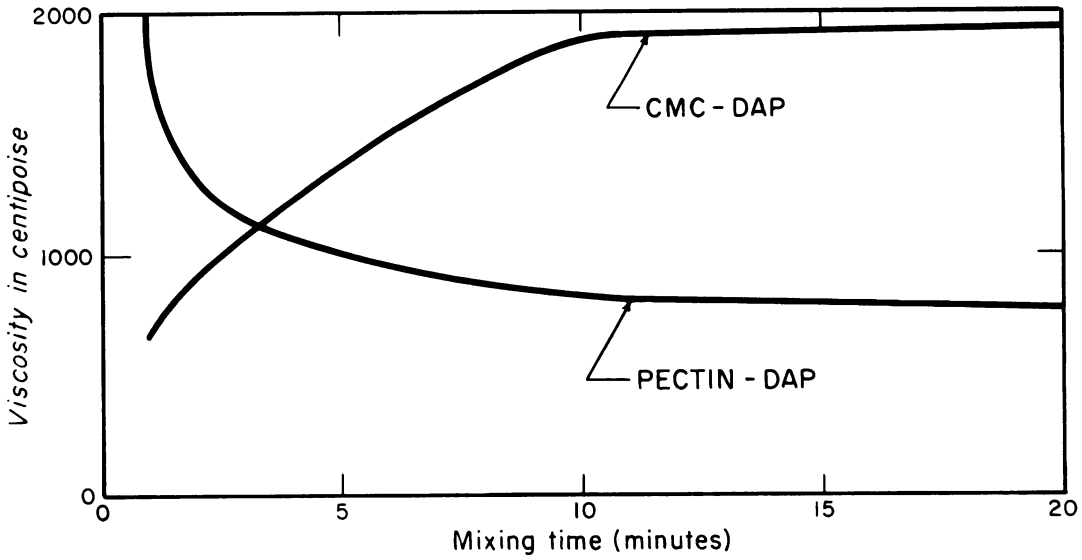

Figure 3.--Relationship of mixing time to final viscosity (Source: Monsanto Chemical Company 1962).

viscosities cannot be obtained if the calcium bicarbonate content of the water is more than 500 ppm (Monsanto Chemical Company 1962).

Viscosities in the range of from 800 to 2,000 centipoise are desirable for good air tanker drop patterns and fuel coverage. Liquids within this range are easy to pump through the normally short distance and large diameter transfer lines found at most air tanker bases. Pectin-DAP is particularly easy to handle.

Although the great bulk of the material in the CMC- and pectin-DAP mixtures is in pellet form, there is a dust problem from the smaller mesh particles. While this problem is not as severe as with bentonite or borate, some provision should be made for respiration equipment during prolonged mixing.

Both retardants are very slippery when wet. Care is needed when walking around spilled material--particularly when climbing on mixing equipment and aircraft.

CORROSION

Ammonium phosphates are known to be corrosive to several metals found in aircraft, including aluminum, copper, brass, and bronze (Van Kleeck 1942, Unlig 1948, Hatfield et al. 1958). However, there has been general disagreement about how serious a problem corrosion is in operational air tanker use. Laboratory studies show corrosion rates to be high, yet mono-ammonium phosphate has been used in air tankers for several years in the Southeast without noticeable corrosion.[1/]

1/ Memorandum to the Chief, U.S. Forest Service from John B. Spring, Assistant Regional Forester, Southern Region, Atlanta, Ga., March 28, 1962.

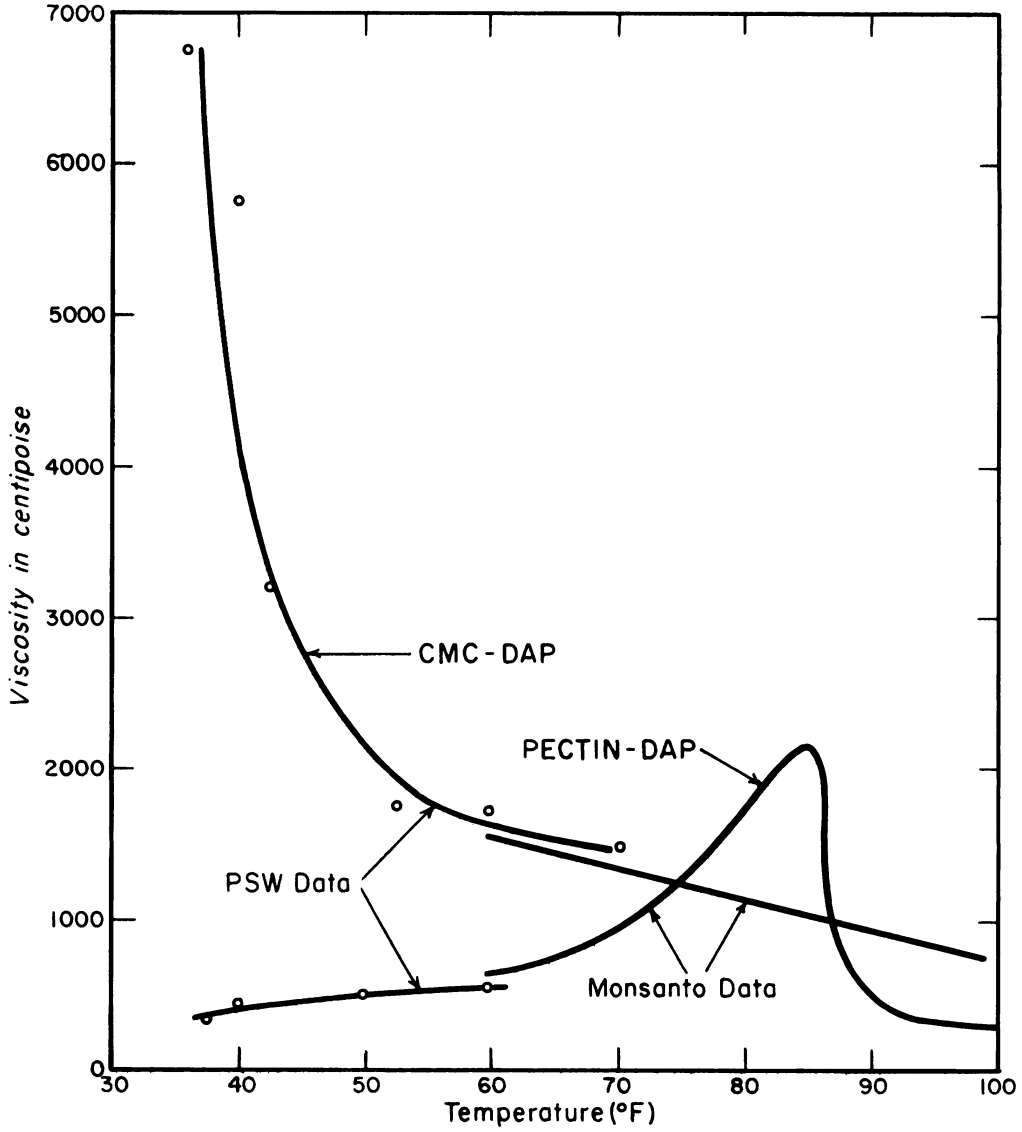

Figure 4.--Effect of temperature on viscosity.

In the tests reported here, one N3N and one TBM were each equipped with sets of test metal strips exposed to possible corrosion by viscous DAP at three different places on the airplane (fig. 5). A fourth set was kept at the airport as a control. After several drops of retardant over a 5-week period, the strips were removed and analyzed for weight loss and tensile strength (table 2). Fatigue resistance tests are going on at the Arcadia Equipment Development Center at the time of this writing.

The sodium silicofluoride used in the mixture proved to be an effective corrosion inhibitor for aluminum. No inhibitors were used for copper or bronze. In some cases copper lost the equivalent of 2.6 mils per year based on continuous operation (i.e. flying or standby) throughout the fire

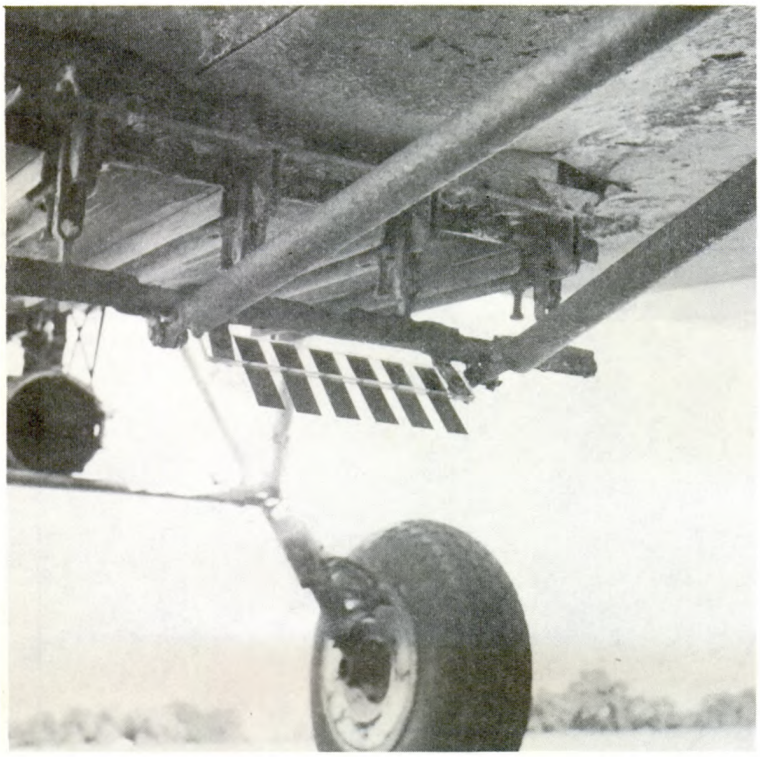

Figure 5.--Test metal strips mounted near the drop gate on an N3N air tanker. Similar strips were mounted near the tail and inside the tank.

season. There was no detectable change in tensile strength. The corrosion effect on bronze was similar to that on copper.

Judging from the results of these tests, corrosion should not be a problem if corrosion inhibitors are used and if delicate copper or copper alloy parts are protected and the airplane properly maintained.

AMMONIA ODOR

Although viscous-DAP is not toxic, it tends to give off ammonia when dropped through the air or applied to a fire. Fire crewmen--especially those caught in the path of the drop--complained that the fumes "took their breath" and temporarily stung their eyes, but all agreed that it was not a serious problem once they knew what to expect.

CONCLUSION

These operational tests from air tanker bases in California, then, have confirmed earlier tests indicating that the viscous DAP solutions are superior to any other presently known fire retardant. Corrosion does not seem to be a problem if inhibitors are used and equipment is properly maintained.

Some problems still remain regarding the storage characteristics during prolonged periods in the hot summer months. The viscosity of the solutions can be affected both by bacterial action and by high temperatures. There are no problems in storing the dry materials.

The search for new retardants will continue, of course, and there is considerable room for improvement in the viscous DAP blend, but for the near future at least, it looks as if this retardant will be our best weapon in the aerial war against fire.

Table 2.--Weight loss and tensil strength of metal strips exposed to viscous DAP

Metal & location on aircraft[1]	Weight loss		Tensil strength[2]
	Test 1	Test 2	(Test 1)
	Mills/yr.[3]	Mills/yr.[3]	P.S.I.
Aluminum			
Tank	0.01	0.00	42,390
Gate	.00	.00	45,825
Tail	.00	.00	41,700
Control	.01	.01	41,700
Copper			
Tank	1.55	2.54	32,850
Gate	1.29	.72	31,025
Tail	.78	.44	31,135
Control	.00	.00	30,725
Bronze			
Tank	2.17	1.80	96,250
Gate	.58	.72	96,300
Tail	.15	.15	92,600
Control	.00	.00	97,800

[1] Strips mounted on an N3N air tanker.

[2] Metal exposed for 264 hours. During this period aircraft was used on 14 fires and received routine maintenance.

[3] Weight loss determined to 0.1 milligram and converted to mills of metal lost per year, assuming continuous operation (standby or flying).

ACKNOWLEDGMENT

The success of these tests has been the result of a cooperative effort by fire control and research agencies, participating chemical companies, and many persons. We are particularly grateful to:

Hemet Valley Flying Service
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Hill's Flying Service
Monsanto Chemical Company
Shell Chemical Company
Ventura Coastal Lemon Company

NOTE: Use of proprietory or brand names is sometimes necessary to report factually on available data. The Station neither guarantees nor warrants the standard of the product, and use of the name implies no approval of the product to the exclusion of others which may also be suitable.

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* Address requests for copies to originating office.